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Response

Remarks

Reconsideration of pending Claims 1-73 and 101-129 is respectfully requested.

The claims have been amended to clarify Applicant's method as claimed, whereby:

- A contact opening is *filled* prior to performing the heat treatment.
- The fill within the opening has a thickness of *500 angstroms or greater*.
- The fill of *at least 500 angstroms* is heat treated to remove chlorine (or other component).
- The component is removed *throughout the thickness* of the contact.
- The contact has no substantial cracks – and does not peel away from the sides of the opening.

No new matter is added with these amendments to the claims, which are intended to merely clarify language used in the claims and/or the subject matter claimed. The scope of the claims is intended to be the same as before the amendment.

Rejections under 35 U.S.C. § 103(a)

The Examiner maintains the rejection of Claims 1, 2, 3-9, 11-14, 16-19, 21-24, 26-28, 30, 31, 33-35, 37, 38, 40-45, 49, 68, 71, 101-105, 112, 114, 116, 120, and 121 as obvious over Wang (US 2002/0155219) in view of Hu (USP 6,436,820). This rejection is respectfully traversed.

In the Office Action at page 2, the Examiner stated as follows (emphasis added):

The rejection is maintained as stated in the paper mailed 2/3/05.

Wang discloses *treatment* of a contact having *a thickness up to 1000 angstroms* [0024] [0048].

Hu exemplifies treatment of a 1400 angstrom film (fig. 3 and col. 4, line 49) at "about 680°C" (col. 5, line 31)...

In the Office Action mailed February 3, 2005, the Examiner stated the rejection based on Hu as follows:

...it would have been obvious to one of ordinary skill in the art to use the higher temperature of Hu et al, which is disclosed to be for the same purpose as the purpose disclosed by Wang et al for the step, with the expectation that the same or similar results would be obtained.

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Thus, the Examiner rejected Applicant's claims as obvious on the basis that:

- 1) Wang teaches plasma treating a contact having a thickness of up to 1000 Å; and
- 2) It would be obvious to modify increase the temperature of Wang's plasma treatment to 680°C based on Hu's disclosure.

The Examiner is in error and has misinterpreted the disclosure of Wang.

Wang does not disclose treatment of a 1000-angstrom thick contact.

At paragraph [0024] below (emphasis added), Wang states that a TiN layer above 1000 Å "can be obtained" – by repeating the film deposition and plasma treatment steps until the desired thickness is provided. Wang does not state that a thickness of 1000 Å is plasma treated to remove chlorine.

[0024] Depending on the specific application, the film deposition and plasma treatment steps can be repeated for additional cycles to yield a composite TiN layer. *For example*, a thick TiN layer can be obtained for thicknesses above 1000 Å. The composite TiN layer typically has a resistivity of less than about 200 μohm-cm, and is well-suited for plug-fill applications for geometries below 0.18 μm.

Rather, Wang deposits a layer of up to 300 Å, treats that layer – and deposits another layer of up to 300 Å – and repeats the plasma treatment and then deposition....until the desired thickness up to 1000 Å is obtained. See paragraph [0022] (emphasis added):

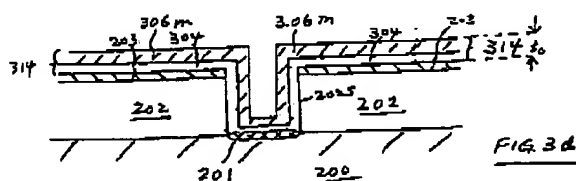
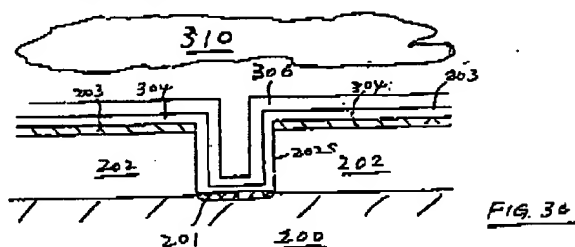
[0022] In one embodiment, a TiN layer is deposited ...The deposited TiN layer, having a thickness of up to about 300 Å, is then exposed to a hydrogen-containing plasma...

The Examiner also cites to paragraph [0048] (see below; emphasis added). There, Wang describes an embodiment in which a composite TiN layer is formed using a two-step process to form a composite layer 314 made of a first TiN layer 304 of less than about 20-25 Å, and a second TiN layer 306 – which is up to 300 Å thick. This structure – having a combined thickness of up to 325 Å – is then plasma treated to remove chlorine.

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That embodiment is illustrated in FIGS. 3c-3d (below). See also paragraph [0048] below (emphasis added).



[0048] In another aspect of the invention, the film deposition and plasma treatment steps are performed in different sequence combinations in order to achieve various desirable film properties. One specific fabrication sequence, for example, involves the formation of a composite TiN layer using a two-step procedure that uses different deposition conditions in the two process steps. This process sequence is illustrated in FIGS. 3a-d. FIG. 3a shows the deposition of a first TiN layer 304 upon a substrate structure 350 similar to that shown in FIG. 2c. The TiN layer 304 is preferably a relatively low stress film that is also relatively thin, e.g., less than about 20-25 Å. In the second step of the process sequence, a second TiN layer 306 is deposited upon the first layer 304, as shown in FIG. 3b. ...This second TiN layer 306 may be deposited to a thickness up to about 300 Å, and may have a film stress that is higher than that of layer 304. FIG. 3c shows the as-deposited TiN layer 306 being exposed to a hydrogen-containing plasma 310, such as that generated from H₂. This plasma treatment results in a composite TiN layer 314 shown in FIG. 3d, comprising the plasma treated or modified layer 306m, which has a reduced Cl content compared to the as-deposited layer 306 of FIG. 3c, and the underlying TiN layer 304. Depending on the specific plasma condition and the thickness of the second TiN layer 306, the underlying layer 304 may or may not be treated by the plasma. For example, if the layer 306 has a thickness less than about 250 Å, the layer 304 will be partially treated by the plasma 310. For a layer 306 thicker than about 250 Å, the layer 304 will probably not be treated. However, since the first TiN layer 304 has a lower chlorine content than the second TiN layer 306 (layer 304 is deposited under a higher NH₃:TiCl₄ ratio condition), whether the layer 304 is plasma treated or not will not significantly affect the resistivity of the composite layer 314. After plasma treatment according to the embodiments of the present invention, there is no noticeable film densification, and the composite layer thickness t_c is approximately equal to the sum of the thickness of the as-deposited TiN layers 304 and 306. Additional cycles of film deposition and plasma treatment can be performed as needed to form a composite TiN layer of desired thickness. In accordance with the present invention, for example, a crack-free, TiN layer 314 having a thickness of over 1000 Å can be fabricated for use in plug fill applications.

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Wang does not teach or suggest heat-treating a thickness of up to 1000 Å. Wang deposits a layer 306 that is "up to about 300 Å" thick – and plasma treats that layer.

Moreover, Wang points out that if a layer 306 is thicker than about 250 Å – an underlying TiN layer 304 will probably not be treated.

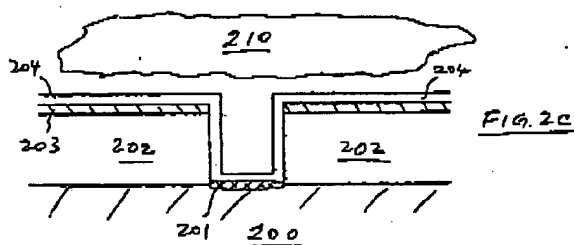
Clearly, Wang does not teach or suggest heat-treating a layer having a thickness of about 500 Å or greater as claimed to effectively reduce the level of a component such as chlorine throughout the thickness of the layer.

Rather, to achieve a thickness of up to 1000 Å, Wang teaches:

- depositing up to 300 Å TiN;
- then plasma treating the layer,

and repeating those steps for additional cycles until the desired thickness is achieved.

Likewise, with the first embodiment, Wang teaches forming a TiN layer 204 of up to 300 Å, and plasma treating that layer to remove chlorine – and repeating those steps of depositing up to 300 Å TiN and then plasma treating the layer – for additional cycles until a desired thickness is achieved. See FIG. 2c, and paragraphs [0022], [0024] and [0037]-[0042], below (emphasis added).



[0022] In one embodiment, a TiN layer is deposited at an $\text{NH}_3:\text{TiCl}_4$ flow ratio... The deposited TiN layer, having a thickness of up to about 300 Å, is then exposed to a hydrogen-containing plasma...

...
[0024] Depending on the specific application, the film deposition and plasma treatment steps can be repeated for additional cycles to yield a composite TiN layer. For example, a thick TiN layer can be obtained for thicknesses above 1000 Å...
...

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[0042] ...In accordance with the present invention, the TiN layer 204 is subjected to a plasma treatment step, as illustrated in FIG. 2c. In particular, the TiN layer 204, e.g., having a thickness up to about 300 Å, is exposed to a hydrogen-containing plasma 210...

Wang clearly teaches performing a plasma treatment on a TiN layer that has a maximum thickness of 300 Å – not on a TiN film of up to 1000 Å, as asserted by the Examiner.

The proposed modification of Wang to alter the plasma treatment to a higher temperature based on Hu – does not provide Applicant's methods as claimed.

The Examiner's combination of Wang with Hu does not teach or suggest Applicant's method of forming a conductive contact by:

- Filling a contact opening prior to performing a treatment to remove an undesirable element, or
- Heat-treating a fill (or layer) having a thickness of at least 500 angstroms to remove a component (e.g., chlorine) from the fill – throughout the thickness of the fill (contact) (or layer).

Accordingly, withdrawal of this rejection is respectfully requested.

Rejections under 35 U.S.C. § 103(a) (Wang with Hu, and Leem or JP '220)

The Examiner maintains the rejection of Claim 115 and Claims 10, 15, 20, 25, 29, 32, 39, 50-59, 61-63, 66, 67, 69, 70, 72, 73, 106-111, 113, 117-119, 122, 123, 128, and 129 based on the combination of Wang with Hu further in view of Leem (USP 6,284,646) or Japan '220 (JP 5267220). These rejections are respectfully traversed.

The Examiner refers to the "paper mailed 2/3/05 and as stated above." In the Office Action mailed February 3, 2005, the Examiner refers to the "paper mailed 8/17/04" – which, in turn, refers to the "paper mailed 2/4/04", which states as follows. With regard to Claim 115, the Examiner stated (Office Action 2/4/04 at page 4):

The combination of Wang et al and Hu et al does not include formation of a boron containing titanium nitride film to form the contact.

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...
It would be within the scope of one of ordinary skill in the art to combine the teachings of Wang et al with the teachings of either one of Leem or Japan '220 to enable formation of the titanium nitride layer of Wang et al having properties disclosed by Leem or Japan '220 associated with the incorporation of boron in the material.

With regard to the remaining claims, the Examiner stated (Office Action 2/4/04 at page 5):

Wang et al fails to disclose formation of one or more of the alternating layers as a titanium boronitride layer.

Leem or Japan '220 are applied as discussed above as providing motivation to form one or more of the titanium nitride layers of Wang et al using boronitride.

First of all – it is again emphasized that **Claim 109** does not recite a boron-containing material. The Examiner's continued rejection of Claim 109 in error. Withdrawal of this rejection of Claim 109 is requested.

The mere incorporation of boron into the TiN material of Wang would not achieve Applicant's method as claimed. As discussed above, Wang specifically teaches limiting the thickness of a TiN layer to up to 300 Å to plasma treat the layer to remove chlorine. This is not Applicant's invention as claimed.

The combination of Wang/Hu with either Leem or Japan '220, does not teach or suggest Applicant's method of forming a contact by:

- depositing titanium nitride (or titanium boronitride) to fill an opening, and
- heat treating a fill (or layer) of at least about 500 Å thick to reduce chlorine throughout the thickness of the fill (or layer).

Neither Leem nor Japan '220 makes up for the deficiencies of Wang and Hu to provide Applicant's methods as claimed.

Furthermore, none of the references teach or suggest forming alternating layers of TiN and boron-doped TiN to form a fill material – as recited in Claims 61-63, 67, 69, 70, 73, 106-108, and 119. See, for example, Claim 61 (emphasis added):

61. The method of Claim 52, wherein the step of depositing the boron-doped titanium nitride layer comprises:

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depositing a layer of titanium nitride over the titanium silicide layer;
depositing a layer of boron-doped titanium nitride over the titanium nitride layer; and
depositing a layer of titanium nitride over the boron-doped titanium nitride layer; and
repeating the foregoing steps to form the boron-doped titanium nitride layer having a
thickness of about 500 angstroms or greater as a multi-layered fill.

The Examiner's combination of Wang and Hu with Leem or Japan '220 does not teach or suggest Applicant's methods as claimed. Accordingly, withdrawal of this rejection is respectfully requested.

Rejections under 35 U.S.C. § 103(a) (Wang with Hu, and Doan)

The Examiner maintained the rejection of Claims 36, 46, 47, 48, 64 and 65 as obvious over Wang in view of Hu, and further in view of Doan (US 2001/0006240). This rejection is respectfully traversed.

The Examiner refers to the "paper mailed 2/3/05 and as stated above." In the Office Action mailed February 3, 2005, the Examiner refers to the "paper mailed 8/17/04" – which, in turn, refers to the "paper mailed 2/4/04." The Examiner stated as follows (Office Action 2/4/04 at page 5):

Wang et al fails to disclose formation of the TiSi_2 layer by PECVD or sputtering.

Doan et al discloses formation of a titanium silicide layer by PECVD [0034] or sputtering [0007] to form a contact.

It would have been within the scope of one of ordinary skill in the art to combine the teachings of Wang et al and Doan et al to enable the TiSi_2 layer of Wang et al to be formed.

The mere formation of a TiSi_2 layer in Wang's method would not achieve Applicant's method as claimed. As discussed above, Wang specifically teaches limiting the thickness of a TiN layer to up to 300 Å to remove chlorine by plasma treatment. This is not Applicant's invention as claimed.

The combination of Doan with Wang and Hu does not teach or suggest Applicant's methods of forming a contact by:

— depositing titanium nitride to fill an opening, and

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- heat treating a fill (or layer) of at least about 500 Å thick to reduce chlorine throughout the thickness of the fill (or layer).

Doan does not make up for the deficiencies of Wang and Hu to provide Applicant's methods as claimed. Accordingly, withdrawal of this rejection is respectfully requested.

Rejections under 35 U.S.C. § 103(a) (Wang with Hu, with AAPA)

The Examiner maintained the rejection of Claims 60 and 124-127 as obvious over Wang and further in view of "applicant's admitted prior art (AAPA)". This rejection is respectfully traversed.

The Examiner refers to the "paper mailed 2/3/05 and as stated above." In the Office Action mailed February 3, 2005, the Examiner refers to the "paper mailed 8/17/04" – which, in turn, refers to the "paper mailed 2/4/04." The Examiner stated as follows (Office Action 2/4/04 at page 6):

Wang et al discloses formation of contact to source/drain to have been known prior to applicant's invention [0006].

Applicant admits the process of forming Al interconnects over contacts to have been known prior to applicant's invention (instant pages 1 and 2).

It would have been within the scope of one of ordinary skill in the art to combine the teachings of Wang [0006] and AAPA to enable formation of a source/drain contact and/or an interconnect.

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The mere formation of contact to an S/D region in the substrate or an interconnect by Wang's method would not achieve Applicant's method as claimed. As discussed above, Wang specifically teaches limiting the thickness of a TiN layer to up to 300 Å to remove chlorine by plasma treatment. This is not Applicant's invention as claimed.

The combination of AAPA with Wang and Hu does not teach or suggest Applicant's methods of forming a contact by:

- depositing titanium nitride to form a layer of at least about 500 Å thick, and
- heat treating the layer to reduce chlorine throughout the thickness of the layer.

Accordingly, withdrawal of this rejection is respectfully requested.

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In sum, the Examiner has failed to establish a *prima facie* case of obviousness based on the combination of Wang and Hu.

Extension of Term. The proceedings herein are for a patent application and the provisions of 37 CFR § 1.136 apply. Applicant believes that a one-month extension of term is required. Please charge the required fee to Account No. 23-2053. If an additional extension is required, please consider this a petition therefor, and charge the required fee to Account No. 23-2053.

Based on the above remarks, the Examiner is respectfully requested to reconsider and withdraw the rejections of the claims. It is submitted that the present claims are in condition for allowance, and notification to that effect is respectfully requested.

Respectfully submitted,



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